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Motor Car Service on Railways

Business Administration

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MOTOR CAR SERVICE ON RAILWAYS

BY

GEORGE HYDE PIKE

THESIS

FOR THE

DEGREE OF BACHELOR OF ARTS

IN

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IN

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

George Hyde Pike

ENTITLED Motor Car Service on Railways

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Arts in Business Administration

In the College of Liberal Arts and Sciences

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INTRODUCTION.

All railway service may be divided into two divisions, namely; local service and through. The local service may be further subdivided into main line local, branch line, and surburban service. Each of these services has been and as a rule still is operated by regular steam locomotive service. However, during recent years considerable competition for parts of the local traffic has arisen out of the development of independent electric railways, and while electrical haulage has been adopted to some extent by the railways, it has not been adopted on any elaborate scale on account of the expense of equipping the line. The problem of meeting this competition is a serious one. There is also the problem of stimulating traffic on branch lines when business is not profitable. An attempt to meet both of these problems and also avoid electrification, has resulted in the development of the self propelled motor car, using either steam, gasoline, or stored electric power as the prime mover.

The first serious attempts were made some twenty years ago. They were unsuccessful. At the present time, however, no question can be raised as to their success or their feasibility under certain conditions.

Experiments came at different times in the various countries. Success, however, came to England and Hungary in 1903 with their steam cars, and to Germany and the United States in 1906 with their storage battery and gasoline cars.

EARLY DEVELOPMENT.

The earliest attempts to build self-propelled cars came between 1872 and 1874.(1) Dr. Lamm built a kinetic steam motor in 1872 to be used out of New Orleans.(2) The water carried on the car was stored at a high heat and pressure (about 700 lbs. per square inch) and passed through reducing valves where it vaporized, and on to an ordinary steam engine. In 1783 an Englishman, Mr. Rowan, built a steam car designed after the locomotive type which had a very small boiler and carried a pressure of only 100 lbs. per square inch. He repeated his experiment the next year, but the cars found no market until thirty years later when the London and South Western, the Great Western, and the Taff Vale all purchased cars designed much as Mr. Rowan's cars were designed. In 1874 Leon Francq attempted the second kinetic steam car and tried it out on the Paris and Orleans Railway of France.

None of these early cars, however, met with success. The designers were either following old methods in developing the new type of car or were using methods too radically different to be successful.

From this time on motor car development languished until about 1879,(3) when one steam car was tried by the Erie. From 1879 until about 1903 almost every variety of car was experimented with in different countries. The steam car showed to better advantage in all these latter trials, and in 1903 we find the real development of steam motor cars beginning in England.

(1) R. R. G., May, 1898.
(2) R. R. G., Oct., 1906.
(3) R. R. G., Oct. 1898.

DEVELOPMENT IN ENGLAND.

The Great Western appointed a commission which, after collecting data from all over the world, recommended that the road adopt steam cars to compete with local electric service and bring their local business back to normal.(1) In 1904 the Great Western tried a number of these cars.(2) The first cost was $9,700.00 each. The results were very satisfactory. By the end of the year they had twenty-five cars in service and were building them as fast as they could. Their intention was to put cars on all outlying lines. The advantages claimed for their cars were great flexibility, and low cost of operation; since these cars saved one member of the crew, needed no station, or station force, and required no switching.(3) They had a seating capacity of from forty-six to fifty-two, varying according to the size of the baggage compartment.

The Taff Vale, Great Central, Great Western, London and North Western, London, Brighton and South Coast, and London and South Western all purchased cars of practically the same size, power and capacity during the next five years.(4) All these cars were steam with the exception of five (Two on the London, Brighton and South Western, two on the North Eastern and one on the Great Northern) which were low powered gasoline cars. These latter cars were complained of on various grounds, chiefly the higher repair and fuel cost and the greater unreliability of the new type.(5) But the steam cars were without an exception most successful. In fact they were so markedly successful on the Taff Vale that in 1908 we find this road discarding its motor car equipment and putting on light

(1) R. R. G., Sept., 1903, Dec., 1903.
(2) R. R. G., May 1904, Dec. 1904, Feb. 1905, May 1905, Aug. 1905.
(3) R. R. G., Oct. 1906. (4) R. R. G., Feb. 1907. R.A.G., Nov.1908.
(5) R. A. G., 1913.

steam trains to handle the increased business which these popular cars had developed.(1)

Experiments were carried on in the British possessions during 1905 - 1907 and 1913 with both steam and gasoline cars. They were flat failures in Ireland and New Zealand but very successful in Australia on the Queensland Railway, which had five McKeen type cars modified to fit their requirements.

The chief difficulties and disadvantages of the steam type of car, which in England seemed to have been developed with such success, will appear in the succeeding review of the experiences of the Germans.

(1) R. A. G., Nov. 1908..

DEVELOPMENT IN GERMANY.

In 1899 a storage battery car was experimented with on a Bavarian road for hauling light freight and heavy express during the night.(1) The car met with quite a success and several more were built and used, but nothing very definite was done in this line until about 1904 when three types of cars were built and tried.(2) These were a serpollet steam coal or oil fired, a Milnes-Daimler gasoline, and a storage battery car. These cars were tried against a light tank locomotive and car. The latter was by far the most successful, being in service practically all the time and costing considerably less to run.

Motor cars were then forgotten for a while until 1906 when experiments were again made. This time the Germans attacked the problem in their customary systematic fashion. Two steam cars of the Stoltz type, six storage battery cars, and one gasoline electric car were designed and built.(3) The Stoltz cars were similar to the other cars except they used a very high working boiler pressure (250 lbs. per square inch) as is the custom in all Continental designs of steam cars. The battery cars used lead elements because this type of battery is about 60% more efficient than the iron element battery.(4) The gasoline electric car was also the ordinary type with the exception that it was designed to use naptha or benzol rather than gasoline.

The results of these trials settled the matter for the Germans. The steam cars had small and delicate boilers and needed constant repairing.(5) They also subjected the traveller to the annoyances of soot, coal dust, and radiant heat. The chief result of the

(1) R. R. G., July 1899. (2) R. R. G., Oct. 1906, May 1907.
(3) R. R. G., May 1907. (4) E. R. J., Oct. 1913.
(5) Bull. Ry. Cong., Feb. 1914.

experiments on the gasoline ~~and~~ electric car was the valuable experience gained. Both these types were discarded on account of their unreliability. The battery car was apparently subject to none of these disadvantages and was also very reliable. The two disadvantages of this type of car are that the car must first be charged, an operation requiring from two to two and one-half hours, and that when it is charged it can run only a short distance (from sixty to one hundred and ten miles) which does not seem to hinder its use in Prussia.

Other disadvantages that ought to be noted at this point, perhaps, are the car's great weight and inability to take great overloads.

A large number of these cars are in use now. One hundred and ninety-seven were in use January 1, 1914. A great number are operated in duplex or triplex close coupled as one unit by the use of multiple unit control.(1) The only advantage of the three car unit over the duplex unit is the lessened axle loads. In the duplex type they were found to be excessive for the roadbed then in use. The new type reduces the load about one-third and also distributes the load more evenly.

The distance which these cars can run on one charge is from sixty-two to eighty-one or one hundred and twelve miles, depending on the size of the battery employed. By the use of the Edison storage battery it will be possible to increase this range to 186 miles, since this type of battery weighs less and is more compact. The ranges given above are for normal operating conditions on level tangent track. Ordinary grades and curves will cut the above

(1) E. R. J., Oct. 1913.

distances about ten or fifteen per cent.

This car has further advantages of being very simple, clean and safe.(1)

The operating efficiency is about 70% of the battery power. Practically all expenses connected with this type of car are constant except that for the charging power. Therefore, one can say that the cost of this service depends almost entirely upon the price charged for the current supplied. In Germany,particularly where these cars are used, power can be purchased at very low rates, and this type of car is found in consequence to be more economical than the other types.(2)

What appears to be the greatest difficulty of all with the storage battery car is encountered when the schedule is being made up. The schedule for this service must have gaps in it at regular intervals to allow for a full charge, and shorter intervals for boosting charges. When it is remembered that a full charge requires about two and one-half hours and the boosting charge from twenty to thirty minutes, it is readily seen that the making of a schedule presents grave difficulties, since the service must suffer if the car does not allow for charging time, or more equipment must be provided for interchange cars. When power is purchased another difficulty arises.(3) Not infrequently it happens that the time when power is needed will occur at the same time that the local power station is loaded heavily. Then the problem presents itself of not only putting the proper number of gaps in the schedule at the proper time, but of making these gaps come at a time when the local power station can be depended upon to supply the current.(4)

(1) E. R. J. October, 1913. (2) R. A. G. December 1909.
(3) R.AA. G. Oct. 1913. (4) Bull. I. Ry. Cong.. Feb. 1914.

It was thought at first that there would be a possibility of regaining part of the current expended in climbing grades. The results of the German experiments indicate that the line on which this would be economical would have to have long ruling grades of better than 1.43%, since shunt motors must be used in this class of service and they are not as economical of power as the series wound type.(1) At best, however, not more than fifty or sixty per cent of the power so used can be regained and it is doubtful if the increased complication in the construction of the car and its equipment would be offset by this saving. At the present time there is only one of these shunt wound cars in use and it does not seem to be regarded with favor. None have been built since about 1911.

At the beginning of 1914 (the latest date for which figures can be obtained) there were about 200 motor cars in service in Prussia along, 176 being battery cars, sixteen gassoline electric, five steam, and two Diesel electric. They operate over 180 districts (centering about fifty-three charging stations) which aggregate about 3077 miles in length. The mileage of these cars has grown from 132,877 in 1907 to about 5,000,000 in 1913.(2)

When the development of the battery car really began in Germany, it was based on two main ideas, one to improve the service and the other to lessen operating expenses if possible on all the lines of weak traffic which radiated from points where cheap current was available.(3)

The service has been improved beyond a doubt and these cars have added considerably to the revenues of the Prussia Hesse State Railways. The car mile costs of these cars are slightly higher than

(1) Bull. I. Ry. Cong., Feb. 1914.
(2) do.
(3) E. R. J., Oct. 1914.

the corresponding costs of light steam train service, but the costs per passenger mile are only about one-half, since the service is more attractive and more people ride. The costs have been reduced still further during the past five years by turning over the entire battery service to the Accumalatorem Fabrik - Aktien gesellschaft, who not only install the battery and inspect it regularly but maintain the plates and electrolyte, if the minimum mileage per type is reached or exceeded. This limit is based on 1000 complete trips per type and amounts to 62,000, 80,600 and 111,600 miles for the different sizes.(1)

According to the managers of the Prussia Hesse State Railways the real issue at the present time is the increase in the range of their cars and a reduction in the power cost. Both of these have reached their practical limits. This therefore points toward either the gasoline or gasoline electric type.(2) When these have been rendered more reliable there will be no question as to their adoption.

(1) E. R. J., Oct. 1914.
(2) Bull. I. Ry. Cong., Feb. 1914.

DEVELOPMENT IN HUNGARY.

In Hungary the development came a great deal later. For four years up to 1902 the earnings on the branch lines of the principal railroad, the Arad-Csanád Railway, had been very low, only about 3.45 cents per train mile.(1) The Ganz steam car company then put a small high pressure coke fired car on the market. The Arad-Csanad Railway tried the car out and by 1903 thirty of these motors were in service. The statements of that year showed an increase of 3.6 times in the net earnings from branch line service and a large increase in travel.(2)

This increase in business continued until 1907 when regular steam trains were substituted for portions of the motor car service. Before this substitution was made, however, the Arad-Csanad people attempted to haul trailers in connection with the steam motors. This resulted in excessive overloads upon the small and delicate power unit of the car so that in 1907 they ran a series of tests with the motor cars and trailers, and light steam trains. They found that the locomotive burned poorer coal, used less coal and water, and cost less to keep in repair under the new conditions.(3)

At about the same time a benzo-electric car was developed called the "Dracar." This is a very light low powered car in 30, 40, 70, and 90 horsepower sizes. In all these styles, however, the engine is small enough to crank by hand and therefore requires no auxiliary starting apparatus as most other types of gasoline cars do. This car is about twice as expensive to operate as the ~~Gary~~ Ganz steam car, but is is a very attractive car and therefore encourages more people to travel. Although more expensive to operate, no trial has

(1) R. R. G., Sept. 1904. (2) R. R. G. Nov. 1904.
(3) R. R. G., Feb. 1907.

as yet been a failure. Rather, it has been a good investment wherever tried. The type has found extensive use not only in Hungary but in Germany, England, and on the Missouri, Oklahoma, and Gulf in the United States.(1) The popularity of this type may best be illustrated by saying that on the Arad-Csanad Railway of Hungary the mileage of their cars has grown from 67,017 in 1903 to 1,000,000 in 1912.

(1) R. R. G., Feb. 1907.

DEVELOPMENT IN SERVIA AND FRANCE.

The Ganz car has been very popular in Servia. This country tried out the car in 1903 and after using it one year they extended the use of these cars to all their branch lines, finding that they cut operating costs about 75% and increased travel from 200 to 300 %.(1)

France, although one of the pioneer countries in adopting and developing motor cars has had an entirely different experience. .(2) As has been said before, experiments in France date as far back as 1874, but nothing definite was done until early in 1898. when the Chemin du Fer du Nord began its trials of the Serpollet type steam car and a Germany battery car.(3) The Paris, Lyons and Marseilles and the Paris and Orleans made trials of a Great Western type of steam car in 1907. Various roads experimented with these cars but they found that the cars were in the repair shop about half the time. Hence, they discarded their use and continued to employ light tank locomotive and coach.

No other foreign countries have developed motor cars with the exception of those mentioned. A few cars have been used in Siam and in Argentina. Canadian roads have used United States types without exception.

This brief survey of foreign development following such methodical lines gives a very fair introduction to the development in this country which was along all lines at once.

(1) R. R. G., Feb. 1904.
(2) R. R. G., June 1907.
(3) R. R. G., Mar. 1898.

DEVELOPMENT IN THE UNITED STATES.

The steam cars developed in this country followed the lines of English experiments. Both high and low working boiler pressures were tried, as also were the solid and knock-down types of cars. The latter type has the power unit detachable from the passenger compartment and is therefore much easier to repair and it also keeps the car out of the roundhouse and so reduces the expenses of cleaning.

The following roads have used motor cars in this country:

Time Motor Service Was Adopted	Railway
Oct. 1897	Erie
Dec. 1897	Cedar Falls Railway (Iowa)
Mar. 1898	Cincinnati, Hamilton, and Dayton
Mar. 1899	Vandalia
May. 1899	Pennsylvania
July 1903	Baltimore and Ohio
April 1905	St. Joseph Valley Traction Co.
June 1905	Chicago and Alton
Feb. 1906	Delaware and Hudson
Feb. 1906	Union Pacific
July 1906	Canadian Pacific
Sept. 1906	Missouri and Kansas Interurban
Mar. 1907	Rock Island
May 1908	Chicago and Northwestern
Oct. 1908	Tabor and Northern Railway (Iowa)
June 1909	Sante Fe
Dec. 1909	Norfolk Southern
Feb. 1910	Southern
March 1910	Ann Arbor Railway
Apr. 1910	Hocking and Sunday Creek Traction Co.
May 1911	Buffalo, Rochester, and Pittsburgh
Dec. 1911	Nevada Copper Belt
May 1912	Frisco
Oct. 1912	Pittsburgh and Lake Erie
November 1912	Missouri, Oklahoma and Gulf
Feb. 1913	Chicago, Milwaukee, and St. Paul
Mar. 1913	Boston and Albany
Mar. 1913	Sunset Central
Mar. 1913	Buffalo and Lake Erie
May 1913	Holton Interurban Co. (California)
Nov. 1913	Dan Patch Lines (Minnesota)
June 1914	Yreka Railway (California)
July 1914	Minnesota and Northern
Jan. 1915	Motley County Railway (Texas)

Six of the above thirty roads have used motor cars extensively. These are the Frisco, Union Pacific, Rock Island, Buffalo, Rochester and Pittsburgh, Missouri, Oklahoma and Gulf, and the Dan Patch Lines.

Pioneer Attempts in the United States.

The Erie was the pioneer in the United States. In 1897 they built a small steam car which carried only nineteen people and required five men to operate it.(1) The car was remodeled in January 1898 but the size was not increased. The Erie management, however, considered the car successful and ordered a still larger car seating thirty-six people from the Schenectady works. This car required only three operators and was much more reliable than the first car.(2) The Erie used these cars until about 1908. At this time the McKeen Gasoline Car began to be very prominent. The Erie ordered one for trial, and were very well pleased with its operation. This was followed by other orders from the same company.(3) The Erie's experience is characteristic of most of the United States railways, especially those who pioneered in motor car work. Steam was experimented with first. This was followed by the use of either the straight gasoline or gasoline electric type.

Results on the Union Pacific.

The next road of prominence in this country to take up motor cars was the Union Pacific. In 1904 Mr. Kruttschnitt, director of Maintenance and Operation, delegated to Mr. McKeen, Jr., Superintendent of Motive Power at Omaha, the task of designing and building a gasoline car to carry sixty people at sixty miles per hour. At

(1) R. R. G. Feb. 1898. (2) R. R. G. Oct. 1898. (3) R. A. G., June'0.
(4) R. R. G. Apr. and June 1906.

that time such a thing seemed impossible. Still, in the spring of 1905 the first McKeen car appeared. It carried only about twenty people and travelled thirty miles an hour.(1) Still this experiment car proved that an economical and reliable car propelled by gasoline power could not only be built but was practical. By the spring of 1906 seven cars had been constructed. They had now been developed to a point where they could carry fifty-seven people at fifty-three miles per hour. By the summer of 1908 forty-one cars had been built or were under construction.(2) At this time Mr. McKeen resigned from the Union Pacific and took up the personal direction of the newly incorporated private concern called the McKeen Motor Car Works of Omaha, Neb.

At the present time this company has built over 140 cars for about fifty railroads.(3)

The car itself is constructed on radically new lines. It is of all steel construction built like an over-turned racing boat with a wedge shaped parabolic front end, elliptical roof and circular rear. There are no corners or projections other than necessary. The windows are round and dust proof, all ventilation being by Globe ventilators placed in the roof.(4) The round windows combined with the steel construction makes it possible to build the sides of this car like deep bridge girders possessing enormous strength. The end construction of the car beings these two deep girders into one solid unit and so places all stresses upon the sides of the car. The strength and resulting safety of these cars is best illustrated by the the effect of a wreck that occured between two McKeen cars in December 1911 on a curve while the cars were travelling about fifty

(1) R. R. G. Nov. 1906. (2) R. R. G. Aug. 1907.
(3) E. R. J. Oct. 1914. (4) R. A. G. Jan. 1909.

miles per hour.(1) Neither car left the track. No lives were lost, one motorman suffered a broken wrist, all other injuries were minor bruises, and only one window was broken. This is certainly a remarkable record, considering that there were about a hundred passengers in the two cars. Mr. McKeen is without a doubt justified when he says that his car is the "safety first" car, since it is a proven fact that it cannot be telescoped or crushed.

Results on the Rock Island.

The Rock Island, although not a large user of motor cars, has experimented with steam cars perhaps more than any other road in the United States. The results are illustrative of the attitude American roads take toward steam cars. In 1907 the Rock Island purchased a Ganz (described under Hungary) steam car, using 270 lbs. per square inch boiler pressure.(2) The car carried fifty-two passengers at thirty-five miles per hour. This was followed in June 1908 by an order on the American Locomotive Company of Schenectady to build an oil burner.(3) This car was just twice as powerful as the former and attained a speed of sixty miles per hour in the trials.(4) A year later the results of these trials were made public by Mr. Seley of the Rock Island. He said, "The matter of combining a steam engine and a coach is wrong. You can't put it in a round house and you must repair it in the yard.(5) We won't spend money on it."

Results on the Buffalo, Rochester, and Pittsburg.

The Buffalo, Rochester and Pittsburg in 1911 purchasedaa gasoline electric unit designed by the General Electric Company to use in branch line service which was not at that time paying for itself. The normal seating capacity of the car is sixty-nine people

(1) R. A. G., Dec. 1911. (2) R. R. G., Mar. 1907
(3) R. R. G., June 1908. (4) R. A. G. July 1908. (5) R.A.G., June '09.

but ninety-seven may be accomodated by seating three in a seat. A maximum speed of about fifty miles per hour is easily attained. The advantages of electric operation, which means very smooth running, were soon noticed in the increased travel.(1) It has also made a material reduction in the operating expenses on the districts where this car and others of its type have been used. The Buffalo, Rochester, and Pittsburg has used General Electric cars exclusively and they are well satisfied with the results.(2)

Results on the Frisco.

The Frisco is another road which waited until the period of development of the different types was practically over before they attempted their use.(3) A branch of the Frisco, the St. Louis, Brownsville and Mexico Railroad, over which there was little travel but which appeared to have good possibilities, was equipped in 1910 with two trial General Electric Gasoline Electric cars. The results of this trial were very satisfactory both from the operating and traffic standpoints and by the spring of 1912 the Frisco had purchased and was using seventeen of these General Electric cars. The later cars carry ninety-two people and are all steel, seventy feet long with side entrances. They weigh fifty tons and carry a 200 horsepower V-type gasoline engine and standard electric railway motors and generator equipment. The maximum speed of these cars is about sixty miles per hour and their schedule speed is between twenty-five to thirty-five miles per hour when making one stop every two or three miles. These cars are now past the experimental stage and no trouble has ever been experienced with them.(4)

(1) R. A. G., May 1911. (2) E. R. J., Oct. 1914.
(3) R. A. G., May 1912. (4) E. R. J., Oct. 1914.

Results on the Missouri, Oklahoma, and Gulf.

Another road in that part of the country which has successfully used motors under slightly different conditions is the Missouri, Oklahoma, and Gulf between Joplin, Mo. and Denison, Tex. (105 miles) They adopted the "Dracar" which was developed in Austria. This road is paralleled on each side for over one hundred miles by the Missouri, Kansas, and Texas, and the Frisco.(1) It was impossible for them and so get the business for the simple reason that their passenger service was already being operated at a net loss. The only other method of competition open to them was to give better and more frequent service between the competing points. They accomplished this by installing the "Dracar" gasoline electric unit. In November 1911 they tried two cars and were well pleased with the results, and therefore ordered four more. The six cars are still in service and they are considered to be a very profitable investment by the road.(2)

Results on the Minneapolis, St. Paul, Rochester and Dubuque Electric Traction Co.

The The Dan Patch lines operating between Minneapolis and Northfield, Minn. present an interesting case. When the company was formed it was decided that the entire line should be electrified and operated as an electric road from the beginning.(3) Before the road was completed, however, it was found that this policy could not be carried out. After some consideration it was decided to equip the entire line with the General Electric Gasoline Electric cars, both for passengers and freight service. This was done in November 1913. (4) The road now has twelve passenger motor cars and one freight motor tractor. This equipment is so satisfactory that it is very doubtful now if the road will ever electrify its lines.

(1) E. R. J., Oct. 1914. (2) R. A. G., Nov. 1912.
(3) Do. (4) R. A. G., Nov. 1913.

FIELD OF SERVICE FOR MOTOR CARS.

The foregoing brief survey of the types developed in different countries and the fields in which they have been used point better probably than any other way the service in which a motor car can be used. However, a summary of these fields will not be out of place.

The principal thing which has created and sustained the interest in motor cars is the fact that they offer a means of communication at a lower cost than the ordinary light steam train.(1) This fact makes the motor cars useful in three main fields, which are, branch line service, competition with trolley lines or other steam roads, and where traffic fluctuates widely as it does at summer resorts. (2)

The chief uses of motor cars in branch line service are as follows: 1. Where traffic is light but seems to be worth cultivating, as upon the Union Pacific.(3) 2. To fill up gaps in the time table which do not justify regular steam service. The most pointed illustration of this is upon the Prussia Hesse Railways.(4) 3. To improve communication between smaller districts and their political and economic centers by promoting suburban traffic when the regular traffic is light, as the Missouri, Oklahoma, and Gulf have done.(3) 4. To relieve express service of making unprofitable stops, thus enabling them to make increased speed.(4) These are the chief factors brought out in the development on the Railways of Prussia Hesse. In the United States motor cars are used only in branch line working. In England and in Hungary we find motor cars used where the traffic does not justify the regular service.

(1) Bull. I. Ry. Cong., Feb. 1914. (2) R. R. G., Dec. 1904.
(3) E. R. J., Oct. 1914. (4) Bull. I. Ry. Cong., Feb. 1914.

In all these countries, United States, England, Germany, and Hungary, we find that motor cars are used in branch line service to fill up gaps in the time table which would not justify regular steam service and to cultivate weak traffic. This may be considered to be the chief use of these cars.

The following table presents at a glance the whole situation in these countries and illustrates the above statement:

Used.	Country. U. S.	Eng.(2)	Ger.(3)	Hung.(3)
In branch line service	Yes	Yes	Yes	Yes
In competitive service	Yes(1)	slight	No	No
In fluctuating traffic	slight	No	No	No
To cultivate traffic	Yes	Yes	Yes	Yes
To fill gaps in service	Yes	Yes	Yes	Yes
To improve service	No	No	Yes	Yes
To relieve express service	No	slight	Yes	No

There are of course miscellaneous uses to which these cars have been put, such as for private cars, infrequent night service, and in inspection work of an extended nature; still the chief use is and probably always will be in passenger work under the conditions mentioned above.

Before motor cars were adopted ~~were adopted~~ in such service they must have shown that they possessed certain advantages outside of the great advantage of providing a cheaper service.

Advantages.

All types of motor cars possess certain advantages.(3) 1. They are able to move themselves. 2. They are immediately ready for service and, 3. Little expense is incurred in getting them ready. 4. Most cars can run in either direction without turning. 5. Only short sidings and few switching operations are needed at stations. 6. A smaller staff is required to operate them. 7. In temperate

(1) Long Island Railroad. (2) R. R. G., Dec. 1904.
(3) Bull. I. Ry. Cong., Feb. 1914.

climates no housing is needed. 8. It is a very small service unit. 9. They possess good riding qualities and are free from smole and cinders. 10. Their parts are easily accessible. 11. They develop new traffic. (1) 12. The control is very simple. 13. They will handle crowds of varying size.

Most of these advantages and the reasons for them are self-evident. Those mentioned from 9 to 13 inclusive have come up during the last decade.

The following advantages are most important, namely: the ability to move as a unit; no time or expense incurred in preparation for service, and since it is a small service unit, no dispatching is required. Those advantages which have appeared during the last few years are also very important, namely: the easy riding qualities due to the great weight of these cars compared to equipment generally used in branch line working, and cleanliness. These two factors have contributed materially to the development of traffic. The control is so simple on many of the later types of cars that it does not require a skilled man to operate them. This does away with the necessity of training the men and saves the cost of their apprenticeship. The accessibility of parts is exceedingly important when the time for repairs comes. Another very important development with the later types is the increasing ability to take large overloads, or successfully handle trailers, and consequently take care of large variations in traffic. They can do this much better and safer than the ordinary trolley or interurban line since they operate over the comparatively good and well protected right of way of a steam road.

(1) R. A. G., August 1909.

Disadvantages.

Successful as these cars appear to be, however, there are some very grave disadvantages connected with their operation. Practically all cars are operated upon branch lines, or in other words at some distance from a repair shop. The result of this is apparent when the inevitable breakdown occurs. It means that much added expense and labor will be incurred during repairs. Another allied difficulty which has been outgrown largely is, that a combined unit must necessarily be more complicated in its construction and will therefore be in the repair shop more time than a simpler unit. Still another serious difficulty with these cars is that it is almost an engineering impossibility to pack enough power into the space alotted. This means an under-powered car with the resulting difficulties upon grades, during acceleration, which must be high in order to make schedule time when stops are frequent, and in hauling trailers. This inability to take overloads has forced the manufacturing companies to place larger power units in the cars. This of course increases the operating costs, but this disadvantage is materially reduced when it is remembered that the larger power units are decidedly more efficient than the small units. Consequently the increase in expense is very slight.

There is also some difficulty experienced in power transmission. This will be taken up under the gasoline and gasoline electric types.

Another difficulty is the initial cost of these cars.(1) It compares very unfavorably with that of an old light locomotive and worn-out coach. This is an important consideration.

(1) R. A. G., May 1906.

A few of these difficulties have been materially lessened by having reputable firms build the motor cars, rather than the railroads themselves. In this way proper attention can be given to all the minor but very important details of design and construction. Conditions have also been bettered by giving the cars regular and skilled inspection and using them in a more natural and rational manner, rather than by trying to see under what overloads or adverse conditions these small units would operate.(1)

A more detailed consideration of the advantages and disadvantages of the different types will now be attempted. In reality there are only three general types to be considered: steam, gasoline, and storage battery. Still the gasoline car mechanically driven and the gasoline car electrically driven are so dissimilar that they may be properly considered as two distinct types. It is therefore, necessary to consider the steam, "straight" gasoline, gasoline electric, and storage battery cars.

Steam Cars.

An analysis of all cases of steam opeartion gives the following facts: (2)

Length of run, miles	22.6
Miles per day	128.0
Seating capacity per car	47.0
Maximum speed, miles per hour	47.7
Schedule speed, miles per hour	24.0 (3)
Weight of car in tons	51.0
Power of car - horsepower	198.0

(1) Bull. I. Ry. Cong., Feb. 1914.
(2) R. R. G., Mar., Nov., 1898; Mar. 1899; Mar., Sept., Nov., Dec.'04. Feb., June, May, 1905; July, Oct., 1906; Mar., May, Sept., 1907; June 1908;
R. A. G., Sept. 1908; Mar., 1909; Jan. 1912.
(3) Observation of a large number of cases shows that schedule speed is generally one-half the maximum speed.

The advantages and disadvantages will now be taken up in the order mentioned before.

Steam motor cars can move themselves; still time and expense is incurred in preparation for service. They can run in either direction and can switch themselves. Only two men are required to operate them unless this conflicts with the state laws. They do not need housing in temperate climate and they also require no dispatching. They ride very smoothly but there is a good deal of vibration as well as heat, soot, and cinders.(1) They are very complicated and parts are hard to get at. The control of these cars is simplicity itself but they cannot take overloads on account of the small capacity of the boiler. Because of this delicate boiler, instances of these cars being in the repair shops 50% or more of the time ~~is~~ are not uncommon.(2) They are in most cases underpowered or at least have no reserve power. There is no trouble in transmitting power to the wheels.

The saving factor of these cars is the first cost. It is very low, only about $10,000.00.(3) This one fact alone has held the steam car before the public for the last fifteen years. They cost about 14.6 cents per car mile to operate. This is based on the average figures from all countries.

Gasoline Cars.

Formerly there were two prominent types of gasoline cars, the Hall Scott of San Francisco and the McKeen of Omaha. The Hall Scott met with several disastrous accidents and their construction was discontinued. The McKeen Gasoline Car is therefore the only practical gasoline car to consider.

(1) Bull. I. Ry. Cong., Feb. 1914. (2) R. R. G., May 1907.
(3) R. R. G., Dec. 1904.

The following figures afford a good idea of the average conditions of operation.(1)

Length of run, miles	69.7
Mileage per day	167.3
Seating capacity per car	60.0
Maximum speed, miles per hour	60.0
Schedule speed, miles per hour	23.1
Grade, Maximum per cent	1.0
Trailer attached, per cent of time	30.0
Weight of car in tons	34.0
Power of car, horsepower	225.0

These cars are not only able to move themselves, but instances of trailer operation are very frequent, and the added cost is barely noticeable, although it does cut down the speed. These cars are also immediately ready to run, absolutely no time or money being lost in preparation for service. They are, however, only able to run in one direction, but the expense of turning is but trifling as the wyes used for turning can be constructed in the cheapest sort of way. Two men can operate the car. Due to the construction of these cars they ride as well as a car twice as heavy. There is no smoke or smell and the exhaust can be muffled until it is hardly noticeable. This car probably ranks first in the accessibility of parts and it is very easy to repair.(2) The car has an extremely inviting appearance and has cultivated traffic to a remarkable degree. The control of these cars is rather complicated and it requires a skilled mechanic as well as a good motorman to operate one. The McKeen motor has been complained of on account of being under-

(1) R. R. G., May 1899; Mar. 1905; Feb., Apr., June, Nov., 1906; June, May, Aug., 1907;
R. A. G., July, Oct.,1908; Jan., Dec., 1909; Apr. 1910; Dec. 1911; Feb., Mar., May, June, July, 1913; Jan. 1915;
E. R. J., Oct. 1914.
(2) E. R. J., Oct. 1914.

powered.(1) This is the fault of the power transmission rather than the engine which develops more horsepower than any other type of car on the market. Under ordinary operating conditions, however, no trouble should be experienced. Due to the remarkably perfect design and construction of these cars, they are seldom in the shop for general repairs. Most of them are in operation more than 95% of the time. Cars built in 1906 are still in good running order and show no signs of becoming unfit for service.(2) Mr. McKeen believes that the life of all these cars should be from thirty to thirty-five years, which is an exceptional figure and can be accounted for only by the excellent construction of these cars.

The clutch and gear arrangement of the McKeen car is very perfect, giving an efficiency of about 96%. The principle however, is not as good as the cars designed by the General Electric Company, which transmit the power to a generator and from this to motors on the axles. In the mechanical drive a shift of gears is necessary. This reduces the tractive power about 75%,(3) and also subjects the engine to very heavy stresses.

The greatest difficulty of all probably with this type is its first cost, which is from three to four times that of a steam car. (No exact figures are available) This means naturally that there must be a real economic necessity before their cars will be introduced. With all this expense the gasoline car costs but 15.02 cents per car mile to operate.

Gasoline Electric Cars.

The big difference in these cars from all others using gasoline as a prime power is in the transmission of this power to

(1) R. R. G., Feb. 1906. (2) E. R. J., Oct. 1914.
(3) See Graph on page 29.

the wheels. A very efficient light weight generator and standard railway motors are used to accomplish this.

There are three prominent types of this car: the European "Dracar," the Strang, and the General Electric. The Strang car carries storage batteries to absorb excess energy on down grades, and when power to the wheels is shut off during coasting or stops. It uses this stored energy in acceleration and on up-grades. This adds a good deal of weight and there are a number of complicated automatic devices necessary for its operation. These two reasons have hindered its extensive adoption.

Below are the average operating conditions in the United States under which these two types are used.(1) The characteristics of the General Electric unit are shown in two groups, chiefly because the full crew law affects them in the South. The operating conditions are also quite different.

Type Car	"Dracar"	"General Electric"	
		North	South
Length of Run, miles	105	50	100
Mileage per day	210	100	200
Weight of car in tons	30	50	50
Power in horsepower	90	200	200
Seating capacity per car	44	80	90
Maximum speed in miles per hr.	35	50	50
Average speed in miles per hr.	18	23	23
Crew	2	2	3

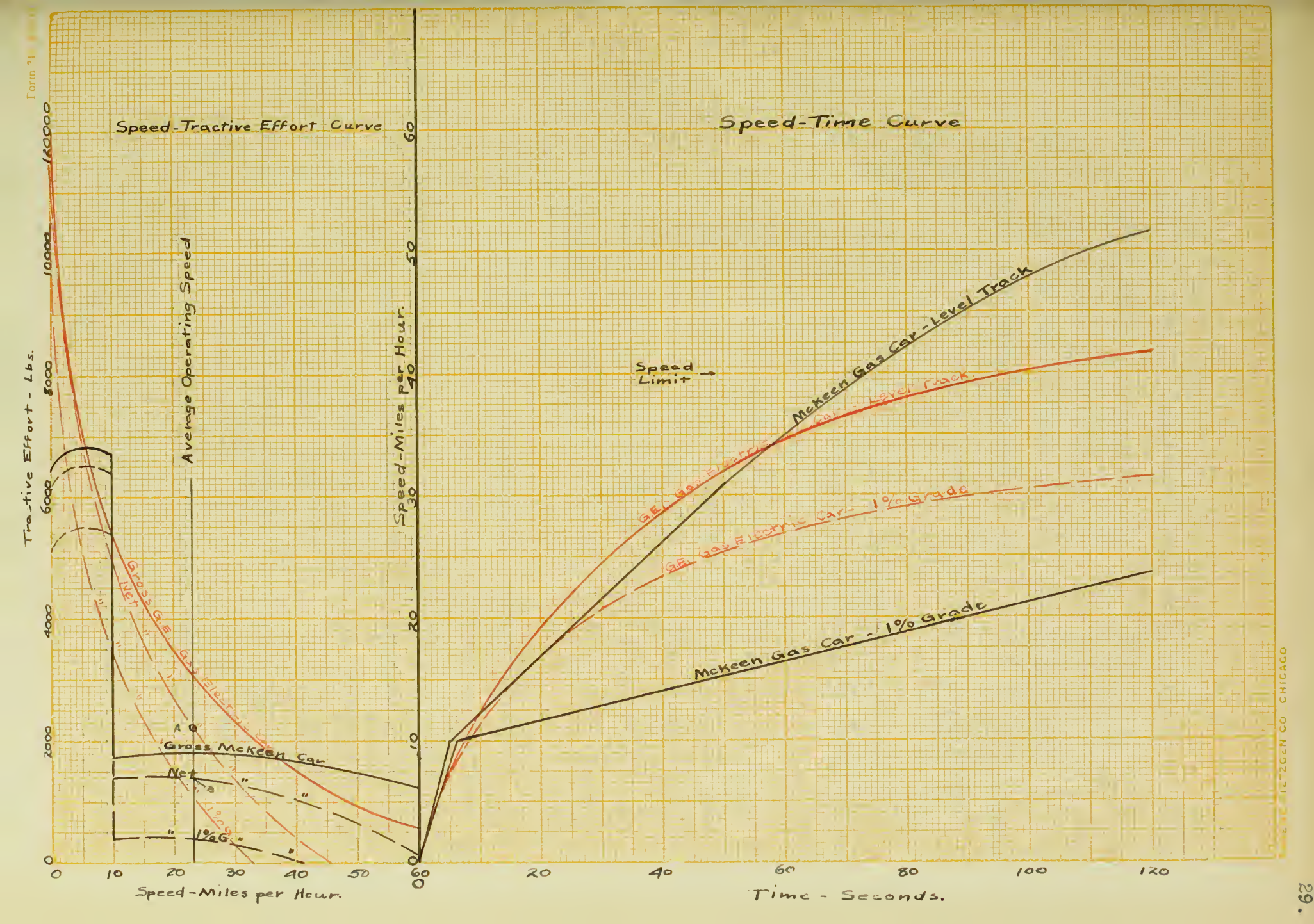
These cars have all the advantages of the straight gasoline unit with the additional advantage of the most perfect power transmission.(2) The efficiency of the electric transmission is about 22% lower than that of the straight gasoline type, (3) but

(1) R. R. G., Apr. 1905; Feb., Sept. 1906; Feb. 1907; May, June, Jan., 1908.
R. A. G., June 1909; Feb. 1910, May 1911, Jan., May, Oct., Nov. 1912; Feb., Apr., Nov., 1913. E. R. J., Oct. 1913.
(2) R. R. G., May 1908; Apr. 1913.
(3) Taking McKeen transmission as 96% and General Electric transmission as 90% for generator and 85% for motors.

it is a great deal more effective, being much smoother and more positive in action. A greater part of the gross weight of the car can be used to develop tractive effort since the motors are on both trucks instead of having the driving power on the front trucks only, as in all other types.

A study of the curve inserted here shows some very interesting facts. The comparison between the McKeen and the General Electric car was chosen because they are beyond a doubt the two most prominent, most used, and most economical types. Both cars are equipped with 200 horsepower motors, the McKeen car however, weighs thirty tons and the General Electric car fifty tons, due to the added weight of the electrical equipment.

For high speed non-stop service the McKeen car is evidently much the best suited. When we consider that operation about say forty miles per hour is hardly ever desired or expected in branch service, it becomes apparent that there is practically no difference between the two types. However, the General Electric unit has a decided advantage at the start over the McKeen car. This is shown graphically by the smooth curve of the first as compared to the abrupt curve of the second car. The result of this is a large reduction in impact stresses upon the engine. Since twenty-three miles per hour is a fair schedule speed, a line has been drawn on the tractive effort curve at that point. The points where the net tractive effort curve is cut by this line are denoted by the letters A and B for the Gasoline Electric and Gasoline cars respectively. This serves to illustrate graphically the average advantage of the General Electric unit over the McKeen car during operation. For level tangent track under normal operating conditions this advan-


Speed-Tractive Effort Curve
Tractive Effort - Lbs.
Average Operating Speed
Speed-Miles per Hour.
Gross G.E. Gas Electric
Net " " "
Gross McKeen Car
Net " "
" 1% G. "
Speed-Miles per Hour.
Speed-Time Curve
Speed Limit →
McKeen Gas Car - Level Track
G.E. Gas Electric Car - Level Track
G.E. Gas Electric Car - 1% Grade
McKeen Gas Car - 1% Grade
Time - Seconds.

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tage is about 61%.

However, level tangent track is not a fair test. In all railway operation grades are encountered. A one per cent grade was chosen for this illustration because it brings out the point very clearly, and because such a grade is very common on branch lines. Under these new conditions the advantage of electrically applied power is easily apparent. The gasoline electric unit accelerates much faster than the McKeen car.

Since these curves are plotted between speed and time, the area under any curve will represent the distance travelled.(1) Taking conditions as they are represented upon the first plot and allowing two minutes to accelerate, we find that the McKeen car will travel 1.09 miles and the General Electric car 1.05 miles. If. however, forty miles per hour is taken as the maximum speed limit for branch line work, these distances will be lowered slightly. The McKeen car will then travel only 1.01 miles and the General Electric car will travel 1.02 miles.

Turning now to the second curve showing operation on a one per cent up-grade, the McKeen travels only 0.56 miles in comparison with the General Electric car, which travels 0.76 miles during the same time. Reducing these figures to percentages it becomes evident that in high speed operation the McKeen has an advantage of about 3.8% (2) over the General Electric car. With operation limited to forty miles per hour there is practically no difference between the two cars. Upon a grade, however, the advantage of the General Electric car over the McKeen unit is 36%. (3) It must be

(1) Areas were computed by Simpson's one-third rule.

(2) $\frac{100(1.09 - 1.05)}{1.05}$ (3) $\frac{100(0.76 - 0.56)}{0.56}$

remembered that throughout this comparison the same power is used on each car, namely; 200 horsepower. Also that the General Electric car is 97% (1) heavier than the McKeen. The tractive effort curve was plotted from accepted figures given in current magazines,(2) checked against figures sent out by the two companies. In computing the resistance of the cars to motion to obtain the net tractive effort, Armstrong's formula was used and in computing the acceleration it was assumed that a force of 100 lbs. per ton would accelerate a car at the rate of one mile per hour per second. Both these assumptions are those widely used in all cases of single car operation.

Storage Battery Cars.

The operating characteristics of the principal cases of storage battery car operation are as follows: (3)

	New York City Third Avenue	Prussia Hesse Railways Germany
Length of run, miles	8	20
Miles per day	58	85
Seating capacity per car	35	50
Maximum speed, miles per hr.	15	37.2
Schedules speed, miles per hr.	6.8	18
Weight of car in tons	7.25	68
Power of car	8.85	170

As the table shows, operating conditions in the two chief instances of battery car operation are very dissimilar.

These cars have practically all the advantages of the modern motor car but they have some very serious disadvantages which totally unfit them for extensive service. These are great weight, low maximum and average speed, and loss of time which is necessarily consumned in charging the batteries.(4) To offset this, they are

(1) $\frac{100(60-30.5)}{30.5}$ (2) R. A. G., part 1, 1913, p. 1180.

(3) R. R. G., July 1899; R. A. G., Dec. 1909; Jan. 1912; Mar. 1913; Bull. I. Ry. Cong., Feb. 1914; E. R. J., 1914. Oct.

(4) R. A. G., Jan. 1912.

absolutely reliable. Prussia used these cars for this reason. They are used in New York City on Third Avenue because overhead or conduit transmission of current was not allowed by the city ordinance.(1) The smoke nuisance pronibited the use of steam cars and the noisy exhaust elimated the gasoline or gasoline electric car. The storage battery car was therefore the only kind of car which could be used.

These cars are also useful where very heavy grades are encountered. There is an instance (2) of this is in Cuba where there is a four mile run averaging three per cent with one grade of seven per cent. There is another case in California (2) where there is a grade of twelve and one-fourth per cent.

(1) E. R. J., Oct. 1914.
(2) Do.

COMPARATIVE OPERATING COSTS OF ALL TYPES IN SERVICE.

The operating advantages and disadvantages of these cars will determine in a large part what type will be adopted, should it be decided that motor cars are to be placed in service. Before this decision is reached, however, the cost of this service must be very accurately determined.

A table is here included which gives as far as possible the total cost of operating different types of car upon the car mile basis. It has been exceedingly difficult to get these figures. The different manufacturing companies will not make them public for the reason that operating conditions have a very great affect upon them. The only source has been, therefore, the reports of the different Railways. But even these reports are affected largely by the method of accounting used, which is by no means uniform.

The costs are given in this table in the order of importance and also according to the time that the type was introduced. The cost of light steam train and ordinary electric street railway service has also been included for comparison.

The costs are divided into fuel, wages of crew or labor, and repairs , both running and shop repairs, since this division is not only logical but is also the most often encountered. The miscellaneous expense represents supplies, as oil and waste, heating and cleaning, and superintendence.

The second table of costs was arranged to show how the different types compared as to total costs. An average of the General Electric cars was used in this rather than the two separate figures.

In all cases, fuel, labor, and repairs cost more in this country than in Europe. The fuel chiefly, because gasoline is used

TABLE I.

Type of car	Cost in cents per car mile					Remarks
	Fuel Power	Labor	Repairs	Misc.	Total	
Steam						
England	3.00	5.00	3.50	5.00	16.50	
United States	3.35	5.30	4.13	2.35 1	15.13	
Average of all cars	3.22	6.52	3.82	3.68	17.24 2	
Best average					14.56 3	
Gasoline						
McKeen Average	3.36	3.94			15.02 4	
Gasoline Electric						
Dracar						
Europe	3.17	2.41	2.51	1.30	9.39 5	A.C.R.R.
United States	4.58	8.90 7	3.13	1.66	18.27	M.O.&G.6
General Electric						
Minnesota	6.03	4.12	2.34	0.89 8	13.38	*
Oklahoma	4.74	7.91 7	2.68	1.63	16.96	Frisco
Average					15.17	
Storage Battery						
Prussia	15.01 9	4.11	4.56	10 6.56 10	20.33	
New York	1.20 11	8.75 12	5.55 13		15.50	
Cuba	11.70 14	2.89 15	2.13 16		16.72	Edison
Steam (Light Train)						
United States	6.00	6.71	4.54	2.15	19.40	
Electric (Street Ry.)						
United States	2.65	1.69	1.02	1.80	7.16	**
Mass., 1909	2.92	6.68	4.44	3.76	17.80 17	

TABLE II.

Type	Total cost in cents per car mile.
Steam train (light)	19.40
Dracar - United States	18.27 6
Steam car - average	17.24
Storage battery - U. S.	15.50 ***
General Electric - aver.	15.17 ***
McKeen car	15.02 ***
Steam - best average	14.56
Electric street railway	7.16

*Dan Patch Lines.
**Small Plant
***Average cost is 15.35

in this country, while the foreign roads use benzine or naptha. The labor and repairs because our wages are higher and the cost of materials is greater than in foreign countries.

This array of figures shows some few things but comments upon the table are necessary. The following numbered paragraphs have reference to similar numbers on the table.

1. Why the miscellaneous expense should be so much lower in this country than abroad is hard to determine. The difference is probably due to the accounting methods and there are no available means of adjusting this difference.

2. This total operating cost is the sum of the average itemized operating expenses wherever given and is therefore not an altogether reliable figure.

3. The best average has been so termed because it is the average of all total operating expense from all railroads who account for the costs in the same way, and is therefore a much more reliable figure than the one above. 2. In most cases the reports did not separate the items; consequently, they were not inserted.

4. The McKeen and the Union Pacific reports give nothing but the fuel, labor, and the total costs.

5. This is a very reliable average total cost, since it is based on the operation of about ninety cars for a six year period.

6. The figures for the Missouri, Oklahoma and Gulf are based upon the first six months of operation after installation. This was also during the winter months. (November - May) Consequently, these figures are much too high and therefore practically useless. It might be added that even under these adverse conditions the service more than paid for itself after the first month.

7. The high cost of labor in these two instances can be attributed to the operation of the full crew law.

8. No reason for the low miscellaneous expense can be given in this case.

9. Since the Prussia Hesse Railways purchase their power at two cents a kilowatt hour, it makes their current cost relatively high.

10. The repair and miscellaneous charge on storage battery cars using lead plates is always comparatively high on account of the rapid deterioration of the plates.

11. The Third Avenue Railway has its own private power plant and it can therefore get current at a very low rate.

12. The above cars run a very low mileage per day; consequently the labor cost is very high when calculated on a mileage basis.

13. The repair cost also includes the miscellaneous charge.

14. As was mentioned on page 32, this Havana line operates over exceptional grades. The effect of this is shown in the very high power cost.

15. Labor is very cheap in Cuba.

16. The Havana line employes the Edison or iron element battery. This battery is famous for its low maintenance and repair costs. The effect of this is seen in the exceptional low repair cost. It must also be remembered that this figure includes the miscellaneous expense.

17. The difference between the total cost per mile for a small plant and for electric railways in Massachusetts is impossible to explain. One would expect the small plant to be the most expensive

to operate, but the second is entirely reliable since its cource is the Massachusetts State Railway Commission Report for 1909. Different accounting methods have more than likely caused the discrepancy.

C O N C L U S I O N S.

Turning our attention now to the second table where the types have been arranged according to the descending order of their total costs per car mile, it is apparent at once that a light practically useless (1) steam locomotive and one coach is about 26.4% (2) more expensive to operate than the average motor car. Of course it is not practicable to secure the low operating costs of trolley line service. These two types of service may therefore be dismissed from our discussion. This done the unit that costs the least to run is the steam motor car. It is, however, only 5.5% (3) lower than the average motor car, or 4.02% (4) lower than the average General Electric gasoline electric car. But when we consider, that the steam motor car can travel only about one-half as far as the General Electric unit per day,(5) that it has only one-third the accelerating power,(6) that the car cannot be as attractively furnished, and that it will subject the occupants to all the annoyances of steam travel, namely, dirt and vibration, it is impossible to believe that this saving of 4.02% in expense is of positive value. Rather it appears not only negligible in amount but of negative value.

This eliminates the steam motor car and leaves only those types which use gasoline as a prime power. The figures for the Dracar are, as was mentioned before, too high and cannot be used with certainty. This reduces this analysis to the costs of the storage battery, gasoline electric and straight gasoline cars.

(1) Useless unless placed in branch line service.
(2) $\frac{100(14.40-15.35)}{15.35}$ (3) $\frac{100(15.35-14.56)}{15.35}$ (4) $\frac{100(15.17-14.56)}{15.17}$
(5) Seed operating characteristics, p. 23 and 27.
(6) The tractive power for speed cars is about 4,000 lbs.

The storage battery car, as has been said before, is not suited for service under ordinary operating conditions. It, however, seems to be particularly well suited to heavy city service and to operation over excessively heavy grades. There are, however, exceptional conditions. The car also costs about 2.18%[1] more to operate than the General Electric car. With these facts in mind it is apparent that the two best types of motor cars for general branch line operation are the McKeen Gasoline and the General Electric Gasoline Electric units.

The McKeen type is about 1%[2] cheaper to operate than the General Electric car. The latter car has, however, many operating advantages over the former. These were brought out in an analytical manner on pages 28-31. These advantages, coupled with the fact that the gasoline electric unit is decidely more simple to operate, are of great importance, and while it is true that the McKeen car costs only 15.02 cents per car mile to operate compared with the gasoline electric cost of 15.17 cents, nevertheless, it does seem that this saving of .15 cents per car mile or 1% of operating expenses is relatively unimportant and should be so regarded.

With all this evidence in mind, it appears to be a certainty, that under the ordinary operating conditions found in branch line working the General Electric car possesses more advantages and fewer disadvantages than other type of car yet developed either in this country or abroad.

In conclusion it is not out of place to say that before branch line working is attempted, with frequent service by motor cars in the place of the scanty service offered by the ordinary

(1) $\frac{100(15.50-15.17)}{15.17}$ (2) $\frac{100(15.17-15.02)}{15.17}$

branch line local train, the entire field should be studied in detail by an expert. First, to determine the conditions of the line and therefore the type of car suited to the district; second, exactly what that service would cost; and third, whether or not there is either enough business in existence or a possibility of developing potential business to the extent that the motor service when installed will not only pay for itself but yield a fair net profit upon the investment.

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